

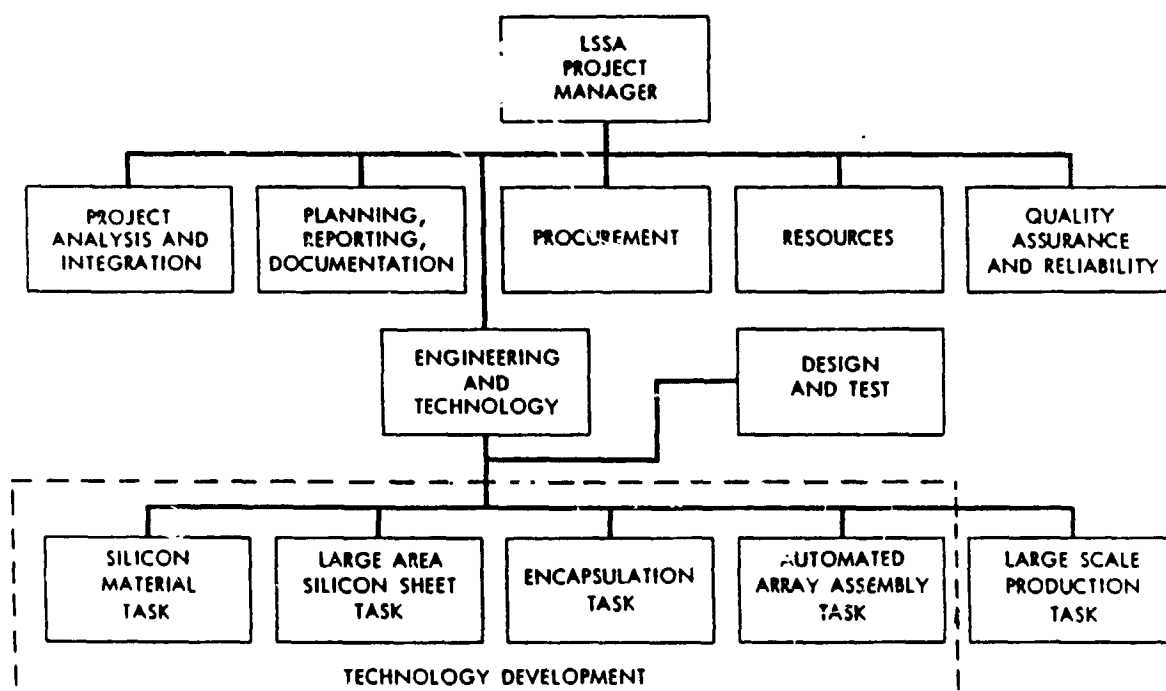
PLENARY SESSIONS

N87-16402

CRYSTALLINE-SILICON PHOTOVOLTAICS SUMMARY
MODULE DESIGN AND RELIABILITY

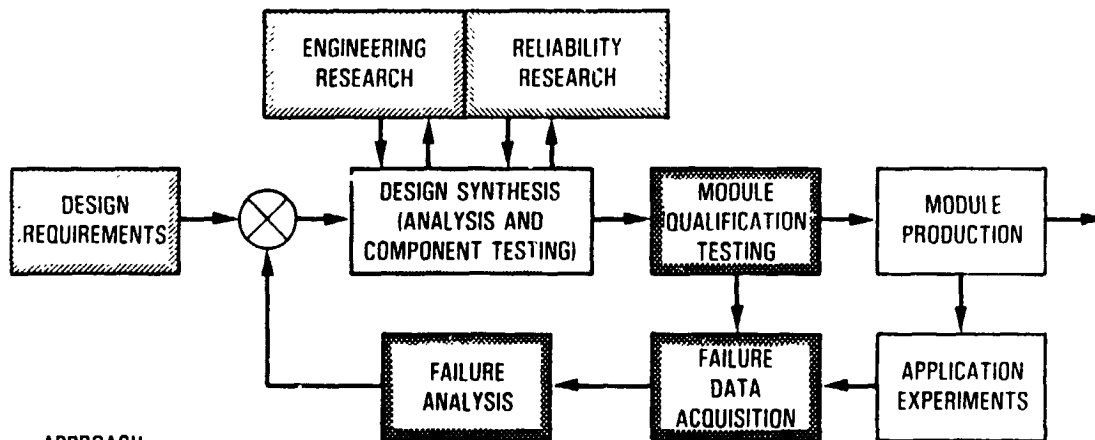
JET PROPULSION LABORATORY

R. G. Ross, Jr.

Low-Cost Silicon Solar Array Project
1975 Organization Chart

PLENARY SESSIONS

Reliability and Engineering Sciences Functional Organization (Closed-Loop Process)



APPROACH

- Derive requirements
- Synthesize designs
- Evaluate designs using laboratory and field tests
- Acquire and feed back performance data
- Develop improved technologies
- Use feedback and technology to improve designs

Design Requirement Generation

- Objective
 - Focus the development of low-cost long-life module technology toward commercial needs of future large-scale PV applications
- Approach
 - Define and develop module and array design requirements for future large-scale applications using private-sector experts and JPL in-house skills
 - Performance
 - Safety
 - Reliability
 - System (Array) Integration
 - Develop near-term versions of the requirements to serve as specifications for procurement of modules for testing and application experiments
 - Iterate the requirements with results fed back from testing experience

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Module Design and Test Specifications

- JPL Crystalline-Si module design requirements have achieved international recognition and use
- Block I: 5-342 First Generation Oct 75
- Block II: 5-342-1B Second Generation Dec 76
- Block III: 5-342-1C Second Generation Update May 77
- PRDA 38: 5101-65 Intermediate Load Center Oct 77
- Block IV: 5101-16A ILC (Third Generation) Nov 78
 5101-83 Residential (Third Generation) Nov 78
- Block V: 5101-161 ILC Applications Feb 81
 5101-162 Residential Feb 81

Design Requirements Accomplishments

- Definitive requirements developed in following areas:
 - Residential building codes (Burt Hill)
 - Utility design practices (Bechtel)
 - National electrical codes (UL)
 - Module safety (UL)
 - Product liability (Carnegie Mellon)
 - Wind loading levels (Boeing/CSU)
 - Array wiring safety (UL)
 - Module flammability (UL)
 - Hail impact levels (JPL)
 - Operating temperature levels (JPL)
 - Module reliability (JPL)
 - Array circuit design practices (JPL)
 - Array structural interfaces (Bechtel, Burt Hill, JPL)
 - System operational interfaces (JPL)

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Design Requirements Current Status and Future Needs

- Most module requirements for large-scale applications are in place for both C-Si and thin-film modules
 - Building code implications understood
 - National Electrical Code (Article 690) in place
 - Module safety requirements (UL 1703) in place
 - Operating temperature levels understood
 - Fire-resistance requirements in place
 - Array/system interface issues understood
 - Wind loading levels understood
 - Hail impact levels determined
 - JPL C-Si module design requirements internationally recognized
- Problem: Transferring the extensive existing technology base to new entries
- Problem: Crystalline-Si module specifications are not sufficient for thin-film modules

Engineering Sciences and Reliability Research

- Objective
 - Develop the engineering technology base required to achieve low-cost, efficient, and safe modules for large-scale applications
 - Develop the technology base required for reliable 30-year life modules
- Approach
 - Identify technology shortfalls through continuous feedback of results from design reviews, qualification tests, field application experiments, and laboratory investigations
 - Draw upon industry experts and JPL in-house experience to develop the generic technology advances required

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Engineering Sciences Accomplishments

- Comprehensive design and construction technology base defined in following areas:
 - Electrical circuit analysis tools (JPL)
 - Module thermal design and test methods (JPL)
 - Module safety design practices (UL)
 - Electrical connection means (AMP, Motorola, Cannon)
 - Fire-resistant module construction practices (JPL, HITCO, Gila River)
 - Bypass diode integration practices (JPL, GE)
 - Array structural designs
 - Residential (Burt Hill, AIA, JPL)
 - Central station (Bechtel, JPL)
 - Array safety system designs (UL)
 - Array/power-conditioner interface characterization (JPL)

Reliability Research Accomplishments

- Definitive technology bases generated for:
 - Glass fracture strength (JPL)
 - Hail impact damage and probability (JPL)
 - Interconnect fatigue (JPL)
 - Soiling levels (JPL)
 - Cell fracture strength (JPL)
 - Hot-spot heating analysis and test methods (JPL)
- Substantial technology generated for:
 - Electrochemical corrosion analysis and test methods (JPL)
 - Bypass diode qualification test methods (JPL)
- Important technology generated for:
 - Electrical breakdown parameter dependencies (JPL, Bechtel, Hughes)
 - Corrosion resistance of C-Si and T-F cells (JPL, Clemson)
 - Module reliability synergisms (JPL, Wyle)



PLENARY SESSIONS

Engineering Sciences and Reliability Current Status and Future Needs

- Most engineering technologies are in place for both C-Si and thin-film modules
 - Structural/thermal design approaches and methods
 - Safety design practices
 - Circuit design approaches and analysis methods
 - System interfacing techniques
- Most technologies are in place for 30-year-life crystalline-Si modules. Exceptions include:
 - Long-term aging of electrical insulation systems
 - Long-term photothermal aging of rear surface films
 - Long-term corrosion of cell metallizations
 - Long-term stability of bonded interfaces
- Significant technology advances required to achieve 30-year-life thin-film modules

Module Development

Objective

- Facilitate the transfer of DOE sponsored technology developments into PV manufacturers and their products
- Define and quantify design deficiencies as an important management tool to focus government and industry R&D efforts at key problems and to assess program performance against its goals

Approach

- Prepare module specifications reflecting future application requirements and encouraging state-of-the-art technology
- Contract with private industry for module design and fabrication
- Conduct detailed evaluation, test and failure analysis of delivered modules
- Iterate design, design reviews, manufacture and tests until successful module qualification

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Module Development Accomplishments

- Nurtured the development of 45 module designs within 15 PV manufacturers over a 10-year period
- Maintained R&D focus on critical-path problems by providing an internationally recognized assessment of PV module electrical performance and reliability
 - Developed unique facilities and techniques for performance assessment and failure analysis
 - Performed qualification tests on over 150 different module designs
 - Block I through Block V
 - DOE application experiments
 - Commercial (U.S. and foreign)
 - Conducted 435 major failure analyses involving 1200 reported design deficiencies



PLENARY SESSIONS

MODULE EVALUATION

ARCO Solar, Inc.

C. Gay

- Customer Is Key
 - Education
 - Experience
 - Confidence
- Relationship Between Laboratory Testing and Real World — Credibility
 - Predictable Energy Delivery
 - Carrisa Plains Within 3% Over 1 Year
 - Predictable Reliability
 - Less Than 1 Warranty Replacement Per 25,000 Modules (Over 500,000 Large Modules in the Field)

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